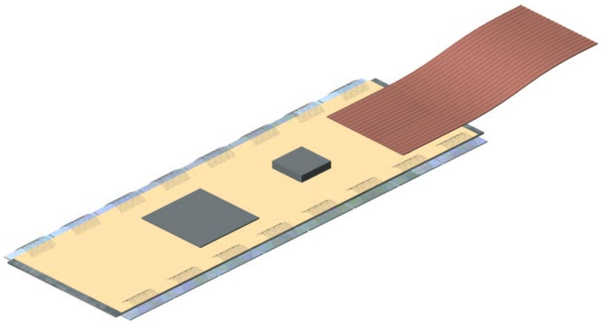
Services

October, 22 1998

Inner Detector Design Review

E. Anderssen, LBNL/CERN

SERVICES AND HOW THEY ARE BROKEN DOWN



- **MODULE SERVICES**
  - POWER
  - CONTROL
  - SIGNAL
  - CONNECTORS/BREAKS
- **COOLING**
  - SUPPLY/RETURN
  - MANIFOLDING
  - TEMPERATURE SENSING
  - CONNECTORS/BREAKS

--MODULE SERVICES DOMINATE SERVICE VOLUME. THERE ARE 1994 MODULES COMBINED IN THE BARREL/FORWARD REGION, AND 234 IN THE B-LAYER.

--COOLING EXHAUST TUBES ARE THE LARGEST SINGLE ITEMS TO ROUTE

--B-LAYER SERVICES, WHILE SIMILAR, HAVE DIFFERENT MODULARITY AND ARE ROUTED DIFFERENTLY

Sizing of Service Cross-sections

Services are sized based on the requirements of the Pixel Modules, Inner Detector environment and the distances to be covered.

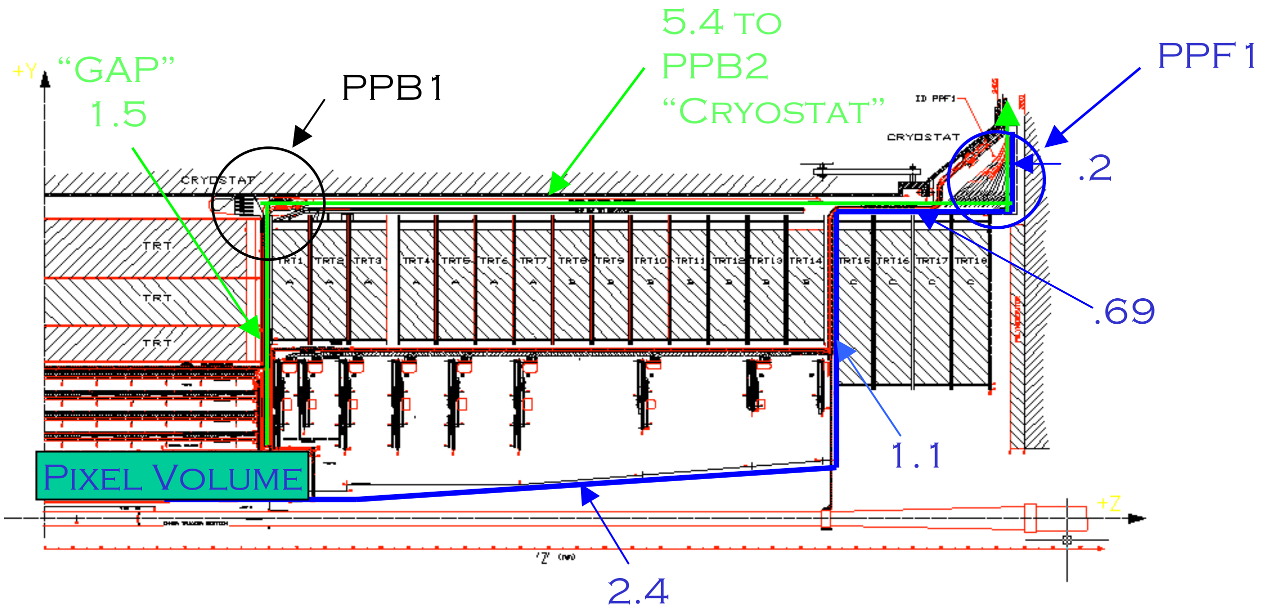
- **Parameters (Determined by Module)**
  - Power dissipation/module
    - .6W/cm^2
  - Number of individual power circuits
    - Vddd, Vdda, Vcc, Vcsel, Optical driver
  - Number of desired measurement circuits
    - Module Temp, Sense Wires (power voltages)
  - Number optical fibers/module
    - Currently 3, Modularity bad in barrel region
  - Cable Properties
- **Parameters (Determined by Cooling)**
  - Required mass-flow to remove heat
  - Fluid properties/flow conditions (function of temp/pressure)
- **Parameters (External)**
  - Allowed dissipation (of services) within ID Volume
    - thermal neutrality
  - Length of Service runs
    - Folds into: pressure drops/voltage drops/dissipation into environment

Module/Power supply Parameters

Power budget	*W/cm^2*		**Power Supplies**		*AMPS*	*AMPS*	*VOLTS*	*WATTS*	*WATTS*
Module	*0.521*			**Circuit**	**Current (Max)**	**Current (USED)**	**Voltage**	**Power(Max)**	**Power (NOM)**
Stave Pigtail	*0.054*	curr_scale	0.8	*Vcc*	0.75	0.48	1.5	1.125	0.72
.5meter PPB1	0.024			*Vddd*	1.5	0.84	3	4.5	2.52
TOTAL	**0.599**			*Vdda*	0.6	0.36	3	1.8	1.08
				PT100	0	0	0		
				Optical link	1.00E-05	1.00E-05	10	0	0
Active Area (cm^2)	*9.216*			VCSEL	1.00E-05	1.00E-05	4	0.0001	0.0001
				Bias Voltage	2.00E-03	1.60E-03	300	0.6	0.48
								Module Power	4.8001

- **Numbers used to size cables are "nominal" at the end of detector life**
- **Power budget normalized to active area**
- **Nothing can increase without negative impact (growth) in service cross-section**
  - additional non-power circuits add 2mm to width of ribbon.
  - Power traces sized on current carried in .5mm increments.
- **Cable Performance requirements have not been considered**
  - Capacitance, noise rejection
  - performance of 80m chain
  - Impact on performance due to connectors

A brief look at external Routing



B-Layer routing is shown in Blue, the rest of the Pixel services are routed along the green path.

- Power cables change size at PPB1 and PPF1 from "Type 1" to "Type 2"
- Type 1 is sized for the 1.5m run from inside Pixel Volume to PPB1 through "GAP".
- Type 2 is sized based on only 2.7m of the 5.4m run from PPB1 to PPB2 along "Cryostat".
- These regions were deemed most critical for both space and dissipation reasons

Power cables were sized based on acceptable voltage drops for the given lengths

B-Layer cables are Type 1 cables out to PPF1

Two options for Module Electrical services (Power and Control)

Round wire with Al-Ka Ribbon

- **Pros**
  - Allows use of less conductor for low current circuits
  - Low current circuits same in both Gap and Cryostat regions (save on art)
  - wires are easier to route
  - wires are cheaper
  - Lower radiation length
  - smaller face area
- **Cons**
  - Uses two technologies
  - Connection of round Al wires is not straightforward
  - Requiring Twisted pair can triple cost
  - Twisted pair negates face area advantage (makes worse than flat)

Aluminum on Kapton Flex

- **Pros**
  - All circuits fabricated at once on same cable
  - Same technology throughout
  - good noise rejection
- **Cons**
  - Metal thickness based on power leading to extra metal in the low power traces due to design rules
  - Artwork different for Gap and Cryostat

It may be that a hybrid solution will work best, though at added cost

Spreadsheet used for Ribbon and Cable Sizing

Al-Kapton

Voltage drop	0.4
Length	150
Al Thickness	4.00E-03
Substrate (Ka)	5.00E-03
Insulator (Ka)	2.50E-03
Voltage drop	0.2
Length*	270
Al Thickness	1.00E-02
Substrate (Ka)	1.25E-02
Insulator (Ka)	2.50E-03

PPB1	Circuit	Calc-Width	Width (.05-pitch)	Gaps (.05-pitch)		Voltage Drop	Power		Area (mm^2)	Eq. Dia mm
	Vcc	0.254	0.250	0.10	(edge)	0.407	0.195		0.101664	0.360
	Vddd	0.445	0.450	0.05		0.395	0.332		0.177912	0.476
	Vdda	0.191	0.200	0.05		0.381	0.137		0.076248	0.312
to((7.5E-03))	*PT100*	0.000	0.050	0.05		0.000	0.000			
to((2.5E-03))	*Optical link*	0.000	0.050	0.05		0.000	0.000			
	VCSEL	0.000	0.050	0.05		0.000	0.000			
	Bias Voltage	0.001	0.050	0.15	(standoff)	0.007	0.000			**Routed Xo**
			Conductor Width	0.10	(edge)		Power Dissapation	1994 Cables	B-Layer	**0.801%**
			1.100	Gap Sum			0.665	1325.1	279.9	
				0.60	Ribbon Width (cm)	Thickness (cm)	Mass (gram)	X0		**Face area**
					1.70	0.0245	9.6713	0.114%		0.04165

Cryostat	Circuit	Calc-Width	Width (.05-pitch)	Gaps (.05-pitch)		Voltage Drop	Power		Area (mm^2)	Eq. Dia mm
	Vcc	0.366	0.350	0.10	(edge)	0.209	0.100		0.3659904	0.683
	Vddd	0.640	0.650	0.05		0.197	0.166		0.6404832	0.903
	Vdda	0.274	0.250	0.05		0.220	0.079		0.2744928	0.591
to((7.5E-03))	*PT100*	0.000	0.050	0.05		0.000	0.000			
to((2.5E-03))	*Optical link*	0.000	0.050	0.05		0.000	0.000			
	VCSEL	0.000	0.050	0.05		0.000	0.000			
	Bias Voltage	0.001	0.050	0.15	(standoff)	0.005	0.000			**Routed Xo**
			Conductor Width	0.10	(edge)		Power Dissapation	1994 Cables		**1.424%**
			1.450	Gap Sum			0.345	687.9		
				0.60	Ribbon Width (cm)	Thickness (cm)	Mass (gram)	X0		**Face area**
					2.05	0.0440	40.2921	0.241%		0.0902

Cryostat w/Wire

Al Thickness	2.50E-03
Substrate (Ka)	5.00E-03
Insulator (Ka)	1.25E-03

Cryostat in Round	Circuit	Area	Width (.05-pitch)	Gap Sum	Width of Cable	Voltage Drop	Power	Xo	Wire OD cm	Eq. Dia mm
AWG 24 0.635mm wire	*Vcc*	3.167E-03	0.000	0.00	0.173	0.231	0.111	Xo Cables	0.087	0.865
MWG 20 1.0mm wire	*Vddd*	7.854E-03	0.000	0.00	0.246	0.163	0.137	0.33%	0.123	1.230
MWG 24 0.600mm wire	*Vdda*	2.827E-03	0.000	0.00	0.166	0.194	0.070	*over 1.143cm*	0.083	0.830
	PT100	1.250E-04	0.050	0.05	*Wire "Width" pack fact=2*	0.000	0.000	Xo Ribbon		
	Optical link	1.250E-04	0.050	0.05	0.585	0.000	0.000	0.06%		
	VCSEL	1.250E-04	0.050	0.05		0.000	0.000	*Over 0.5cm*		
	Bias Voltage	1.250E-04	0.050	0.15		0.020	0.000			
			Conductor Width	0.10			Power Dissapation	1994 Cables		**Routed Xo**
			0.200	Gap Sum			0.318	633.9		**0.674%**
				0.40	Ribbon Width (cm)	Thickness (cm)	Mass (gram)	X0		
					0.60	0.0190	24.2247	N/A		**Face Area**
										0.0552

PPB1 w/Wire

Al Thickness	2.50E-03
Substrate (Ka)	5.00E-03
Insulator (Ka)	1.25E-03

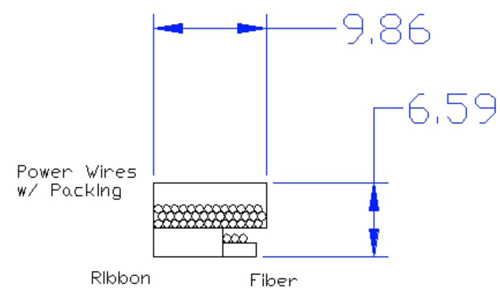
PPB1 in Round	Circuit	Area	Width (.05-pitch)	Gap Sum	Width of Cable	Voltage Drop	Power	Xo	Wire OD cm	Eq. Dia mm
MWG 26 0.500mm wire	*Vcc*	1.963E-03	0.000	0.00	0.146	0.207	0.099	Xo Cables	0.073	0.730
MWG 26 0.500mm wire	*Vddd*	1.963E-03	0.000	0.00	0.146	0.362	0.304	0.21%	0.073	0.730
MWG 26 0.500mm wire	*Vdda*	1.963E-03	0.000	0.00	0.146	0.155	0.056	*over 1.143cm*	0.073	0.730
	PT100	1.250E-04	0.050	0.05	*Wire "Width" pack fact=2*	0.000	0.000	Xo Ribbon		
	Optical link	1.250E-04	0.050	0.05	0.438	0.000	0.000	0.06%		
	VCSEL	1.250E-04	0.050	0.05		0.000	0.000	*Over 0.5cm*		
	Bias Voltage	1.250E-04	0.050	0.15		0.020	0.000			
			Conductor Width	0.10			Power Dissapation	1994 Cables	B-Layer	**Routed Xo**
			0.200	Gap Sum			0.460	916.9	193.7	**0.377%**
				0.40	Ribbon Width (cm)	Thickness (cm)	Mass (gram)	X0		
					0.60	0.0190	7.0123	N/A		**Face Area**
										0.0340

Lengths in cm

CURRENT CIRCUIT INVENTORY

Circuit	Current (Max)	Current (USED)
Vcc	0.75	0.48
Vddd	1.5	0.84
Vdda	0.6	0.36
PT100	0	0
Optical link	1.00E-05	1.00E-05
VCSEL	1.00E-05	1.00E-05
Bias Voltage	2.00E-03	1.60E-03

BUNDLE INDICATIVE OF SERVICE CROSS SECTION



Barrel Cone Bundle

(ROUND WIRE SOLUTION SHOWN)

SENSITIVITY TO CHANGES IN PARAMETERS

- **CURRENT/POWER**
  - SLIGHT SENSITIVITY FOR SMALL CHANGES
    - <10% (+/-)
- **NUMBER OF CIRCUITS**
  - IT IS LIKELY TO INCREASE IN THE CASE OF SENSE WIRES (DOUBLES NUMBER OF LOW POWER TRACES)
    - UP TO 30% INCREASE
- **NOISE REJECTION**
  - TWISTED PAIR DOUBLES WIRE AREA
    - UP TO 50% INCREASE
- **FIBER MODULARITY**
  - CURRENTLY CONNECTORS COME MODULO 12 WHICH DOES NOT EASILY DIVIDE INTO 13 X 3
    - POSSIBLE 5% DECREASE

MODULE SERVICES MAY UP TO DOUBLE IN FACE AREA FROM CURRENT BEST ESTIMATES.

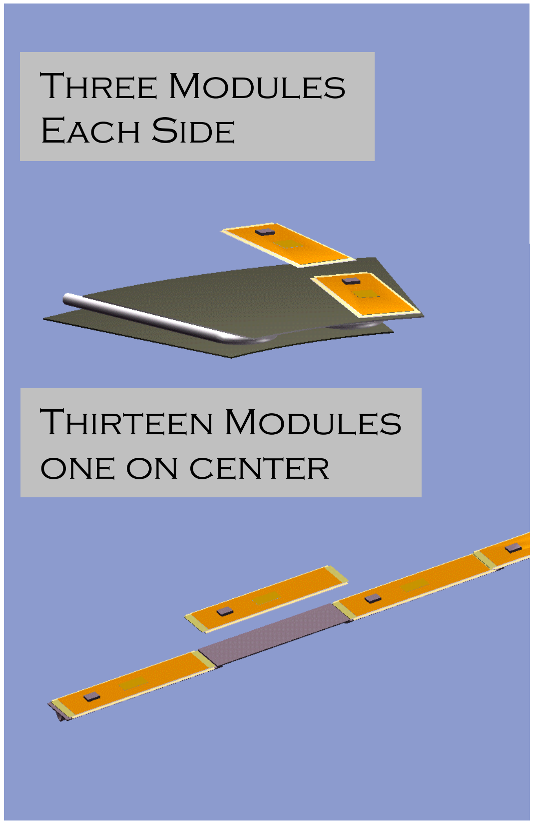
FULL SCALE TESTING OF MODULE POWER CHAIN IS NECESSARY TO DETERMINE THE EXTENT TO WHICH THEY MAY INCREASE

Current Cooling Inventory

- **Evaporative cooling is Pixel Baseline**
- **Cooling modularity**
  - Two staves/sectors per circuit, except B-Layer, which has one circuit per stave
  - possibility of manifolding only exhaust under study
- **Return line sized based on Uniphase coolant**
  - Return line size under study for evaporative flow
  - Assumption that this is conservative
- **Space reserved for uniphase coolant system**
  - Return line to PPB1 is 5.1mm, supply is 2.0mm
  - All tubes laid in at 5.1

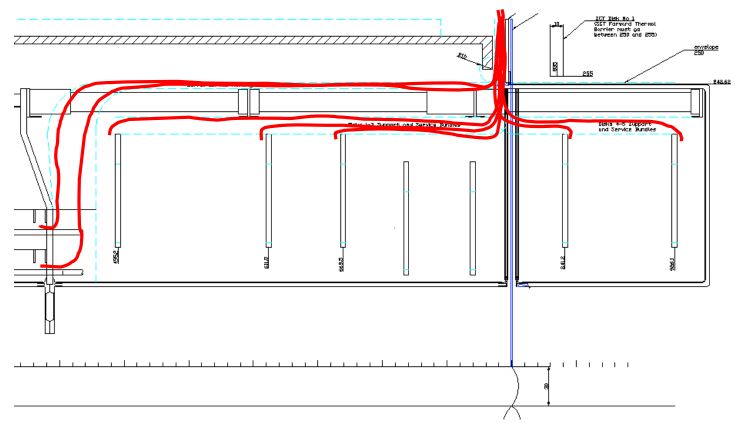
Barrel Layer 1	Barrel Layer 2	B-Layer	Disks	Totals	
56 Staves	42 Staves	18 Staves	60 Sectors	**PPB1**	**PPF1**
28 Supply	21 Supply	9 Supply	30 Supply	79 Supply	9 Supply
28 Return	21 Return	9 Return	30 Return	79 Return	9 Return

Bundling of Services



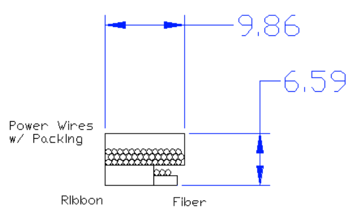
- **Bundle moduli are based on local support elements**
  - Disks have 6 modules per sector with 10*-12 sectors per disk
  - Barrels have 18, 42 and 56 staves with 13 modules per stave
  - Cooling circuits have 2 sectors/staves per circuit.
- **Assembly into global structure**
  - Minimize damage to module/service termination
  - Access during assembly
- **Routing through Pixel Volume**
  - Services go away from IP to minimize mass

Each stave will have the services for 6 or 7 modules leaving at each end
Disk services leave the disk evenly distributed in phi



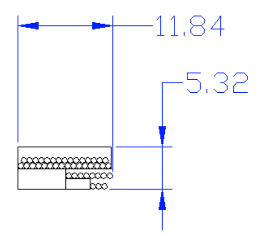
CABLE BUNDLES AS DEFINED IN PIXEL VOLUME

SECTION AA

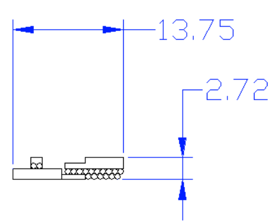


Barrel Cone Bundle

SECTION BB

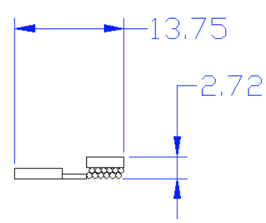


Barrel OD Bundle



Disk 1-3 Bundle

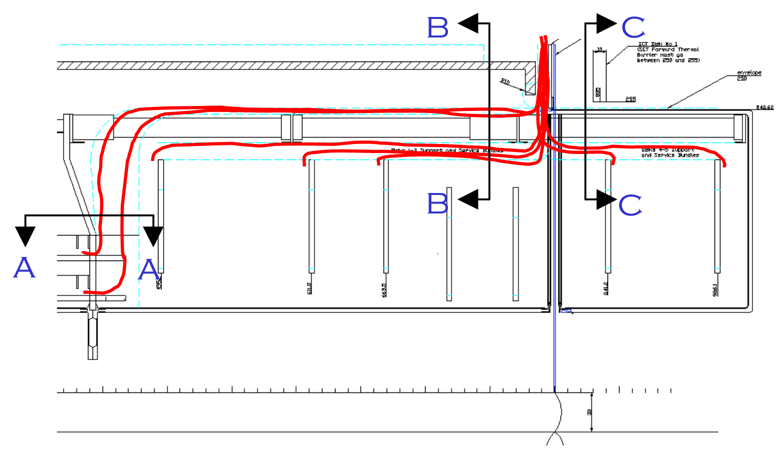
SECTION BB



Disk 4-5 Bundle

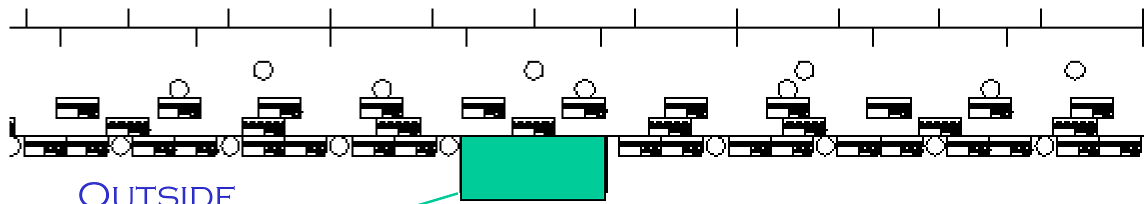
SECTION CC

- **BUNDLES DO NOT ACCOUNT FOR PHI REGROUPING**
  - BUNDLES WILL NEED TO BE INTEGRATED AND BUNCHED IN GAP REGION INTO 8 ANGULAR REGIONS FOR EXTERNAL ROUTING
- **BARREL SERVICES ARE ROUTED ON THE OUTSIDE OF THE FORWARD FRAME**
  - BARREL BUNDLES HAVE SERVICES FOR 7 MODULES
- **DISK SERVICES ARE ROUTED INSIDE OF FORWARD FRAME**
  - DISK 1-3 BUNDLE SERVES 3 MODULES ON CONSECUTIVE DISKS
  - DISK 4-5 BUNDLE SIMILARLY SERVES 2 MODULES



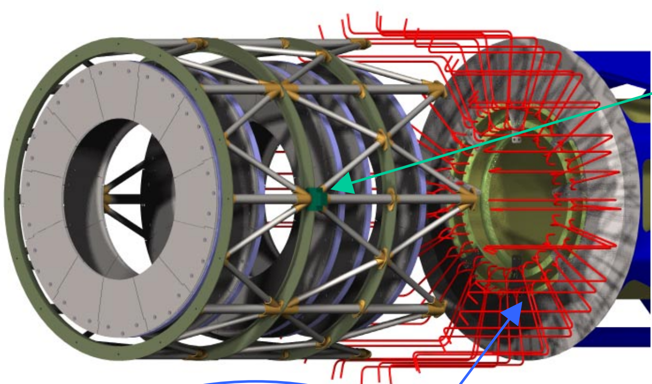
SECTIONS OF "ROUTED" CABLES

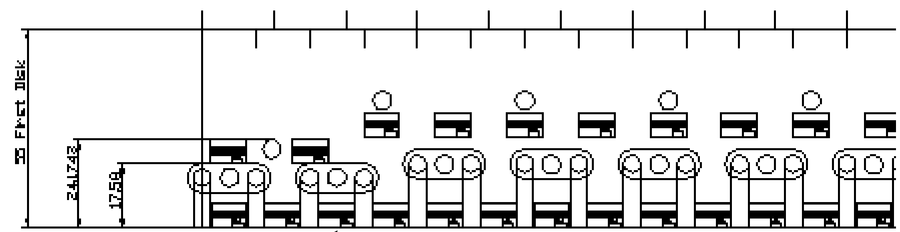
SERVICES OUTSIDE OF FRAME HAVE 10% CIRCUMFERENTIAL MARGIN FOR UNIPHASE TUBE PACKING.



OUTSIDE FRAME

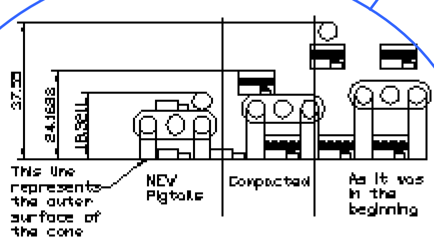
15 X 40 SUPPORT





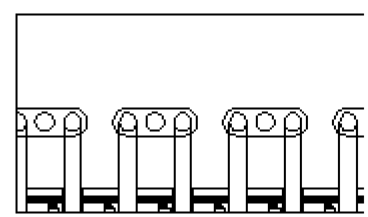
BARREL LAYER 2

CABLE WIDTH LIMITED BY PITCH



PACKING STUDY FOR BARREL SERVICES

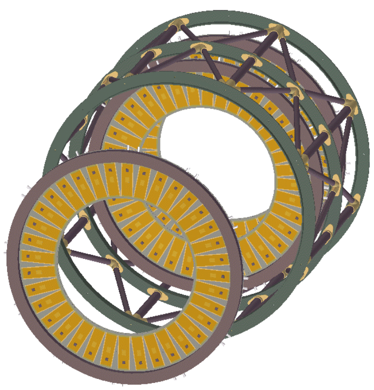
SERVICES EXITING BARREL AFFECT FIRST DISK POSITION.



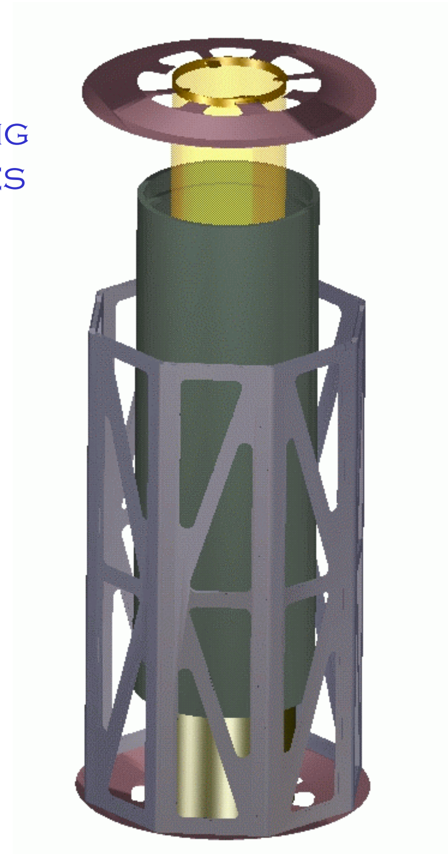
BARREL LAYER 1

Disconnection Locations

Full cabling must be attached to disk prior to insertion



Do not want long pigtails on staves at this stage of Assembly

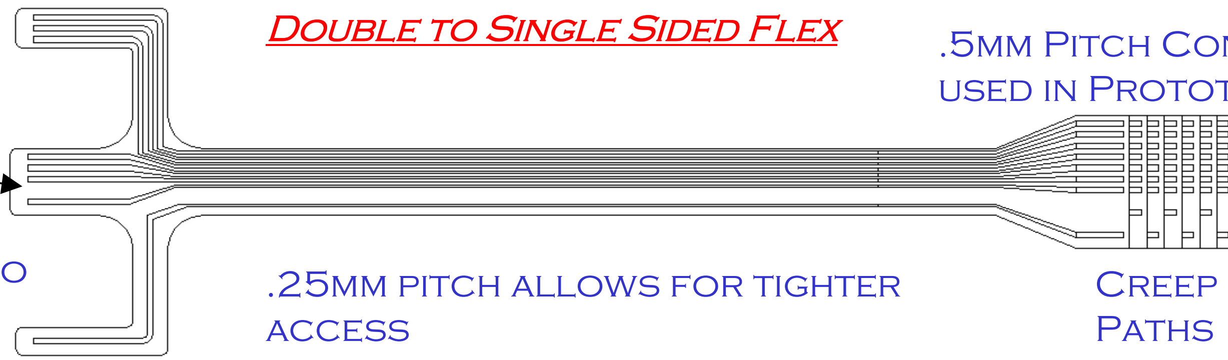


Cables and Tubes do not necessarily break at same locations.

- **Assembly sequence Factors into Breaks**
  - Just outside Support Cone
  - AT Disk Radius
  - At End of overall Structure
  - At Manifolds

CONNECTIONS/BREAKS

DOUBLE TO SINGLE SIDED FLEX



DOUBLE SIDED CABLE ATTACHES HERE

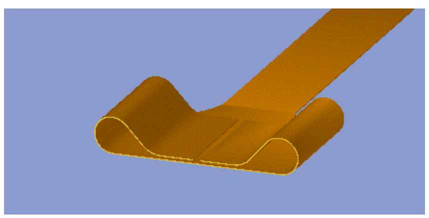
ARMS FOLD OVER TO PICK UP TOP

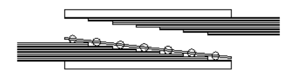
HV

.25MM PITCH ALLOWS FOR TIGHTER ACCESS

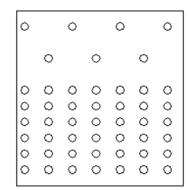
.5MM PITCH CONTACT USED IN PROTOTYPE

CREEP PATHS

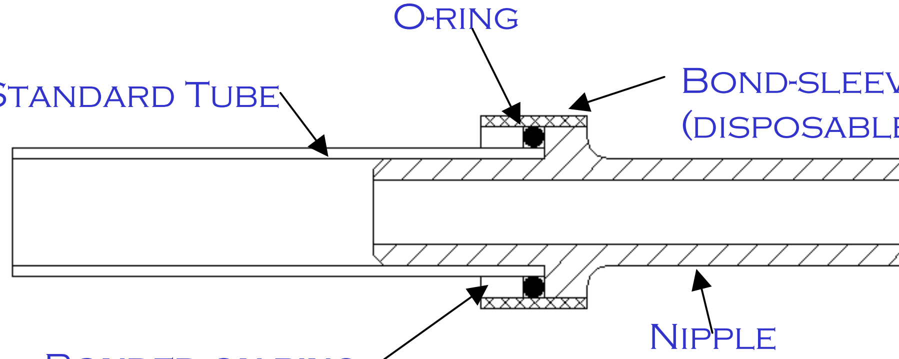




BALL GRID ARRAY CONTACT PAD



SEMI-PERMANENT TUBE CONNECTOR



O-RING

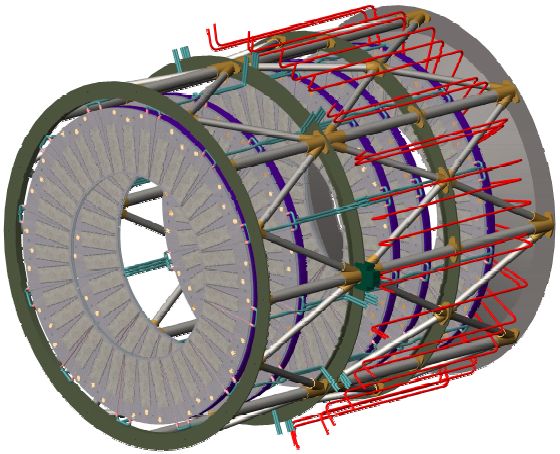
STANDARD TUBE

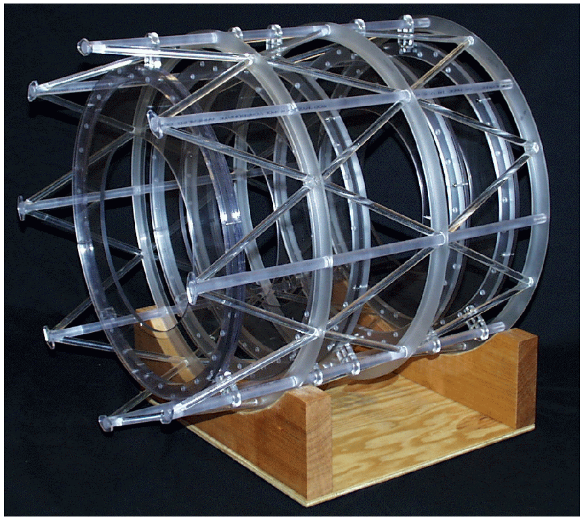
BOND-SLEEVE (DISPOSABLE)

BONDED ON RING

NIPPLE

Remaining Issues





- **Routing needs to be re-done in 3-D**
  - Cable behaviour hard to capture in CAD
  - 3D non structural scale model has been constructed
  - Route services on model, feedback into 3-D CAD
- **Forces need to be estimated**
  - Cooling tubes will respond to pressure and temperature variations–need to estimate loads
- **Couplings and Strain relief need to be investigated**
  - Assembly and subsequent attachment of services will couple the pixel detector to external detectors.
  - Flexible connections need to be rad-hard
- **Connections need to be Prototyped**
  - Aluminum cabling is not easily connected to
  - Commercial connectors are not desirable

Thermal Barrier

22-October, 1998

Inner Detector Design Review

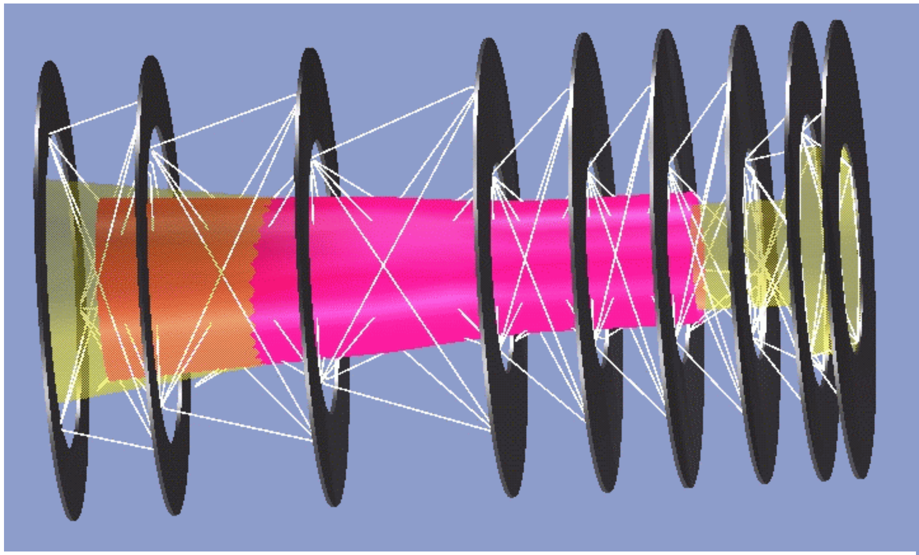
E. Anderssen, LBNL/CERN

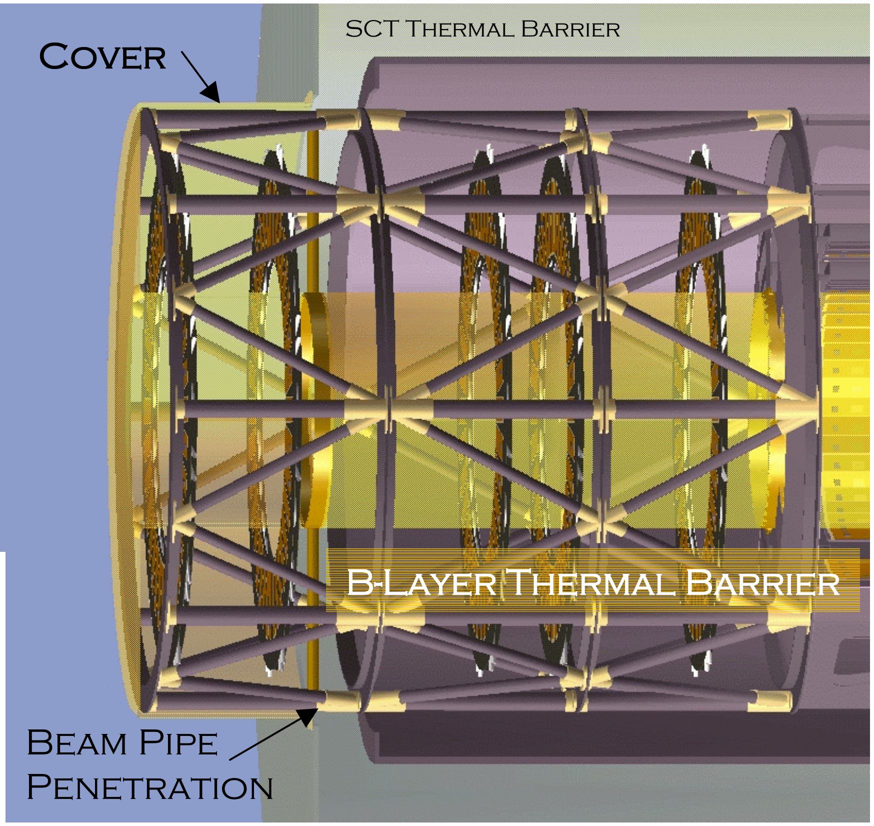
Thermal Barrier Requirements

- The Volume for installing the B-Layer is filled with Cavern Air -- Dewpoint of 13 Deg C
- Detector Volume is as low as -15 Deg C-- Thermal Barrier must stand-off ~30 Deg C thermal gradient in minimal space
- Structure of Thermal Barrier minimized for X0
- No Condensation is allowed on any surface within the detector
- Design requires Knowledge of Installation and Removal Scenarios, Times and failure modes

These requirements lead to an active thermal barrier requiring heat input on the exterior surfaces to meet boundary conditions

Thermal Barriers and Forward Region Space

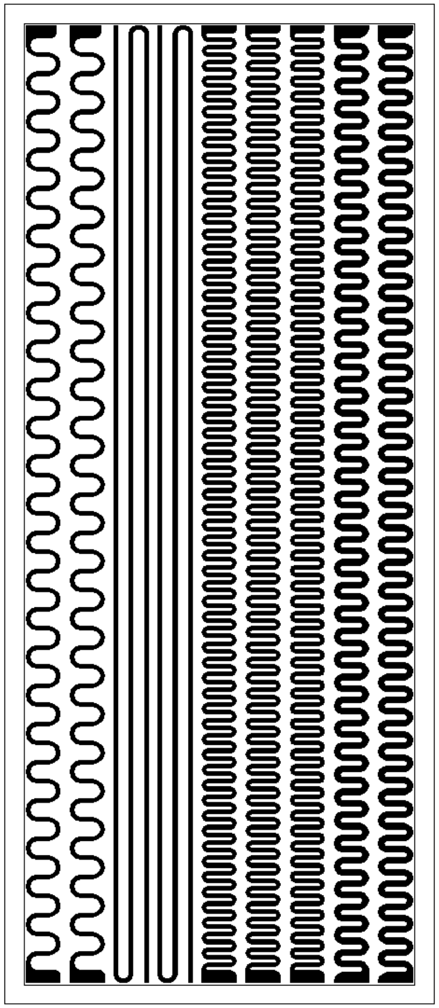




Gold "Cylinder" cone is Forward Region Thermal Barrier. Red cone is Inner Envelope of Current Alignment Grid.

Thermal Barrier is designed to have a warm exterior surface above the dewpoint.
To achieve this with a minimum of thickness and material the exterior is heated actively.

Thermal Barrier Construction

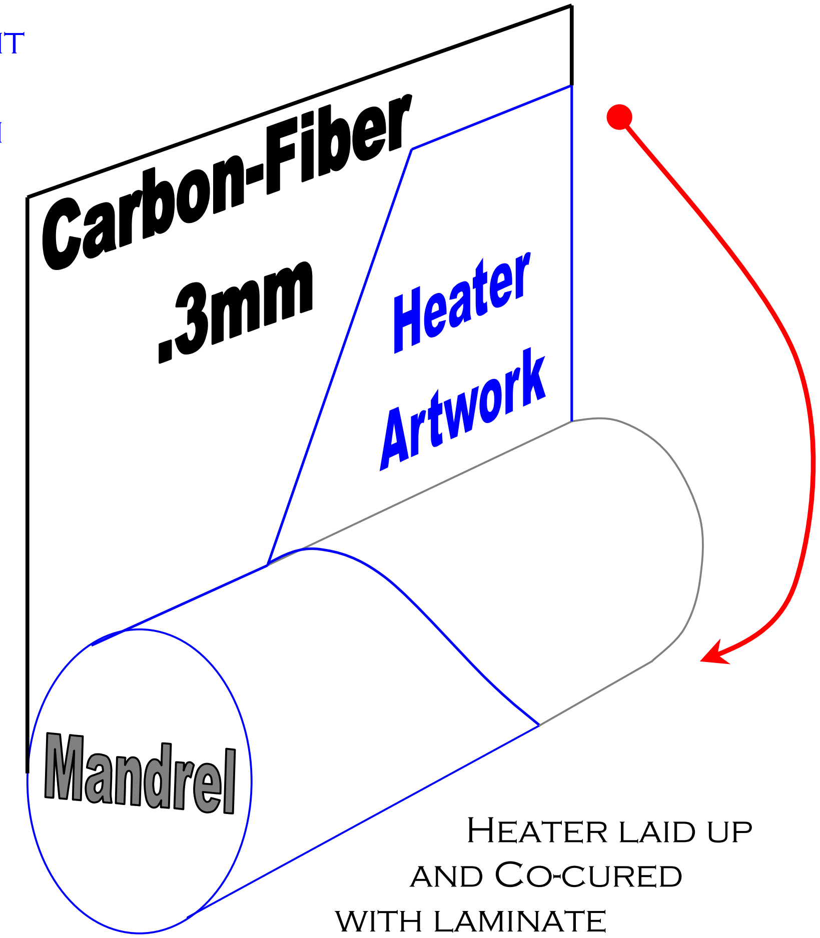


Test Artwork for current Limit testing. Left Sets have equivalent radiation lengths. Slightly more heat is required at penetrations and boundaries

Test program on:
Double-Sided Al-Kapton
20micron AL
50micron Kapton

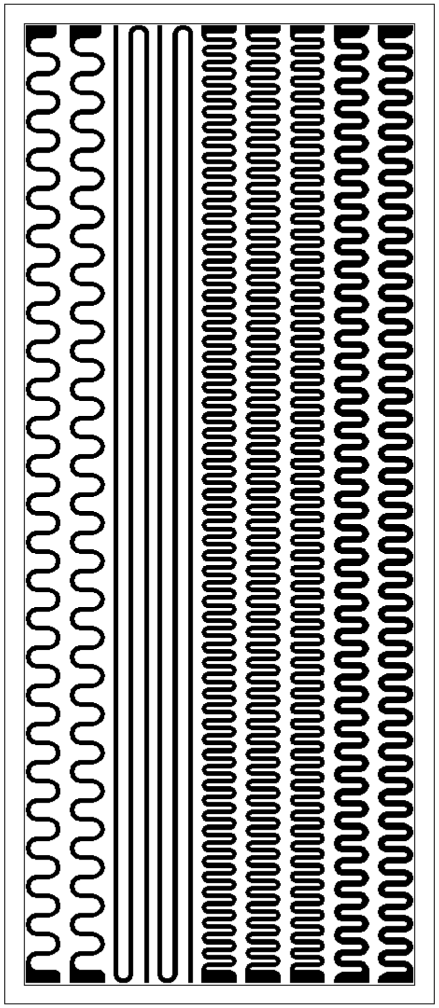
Heater patterns etched in one side

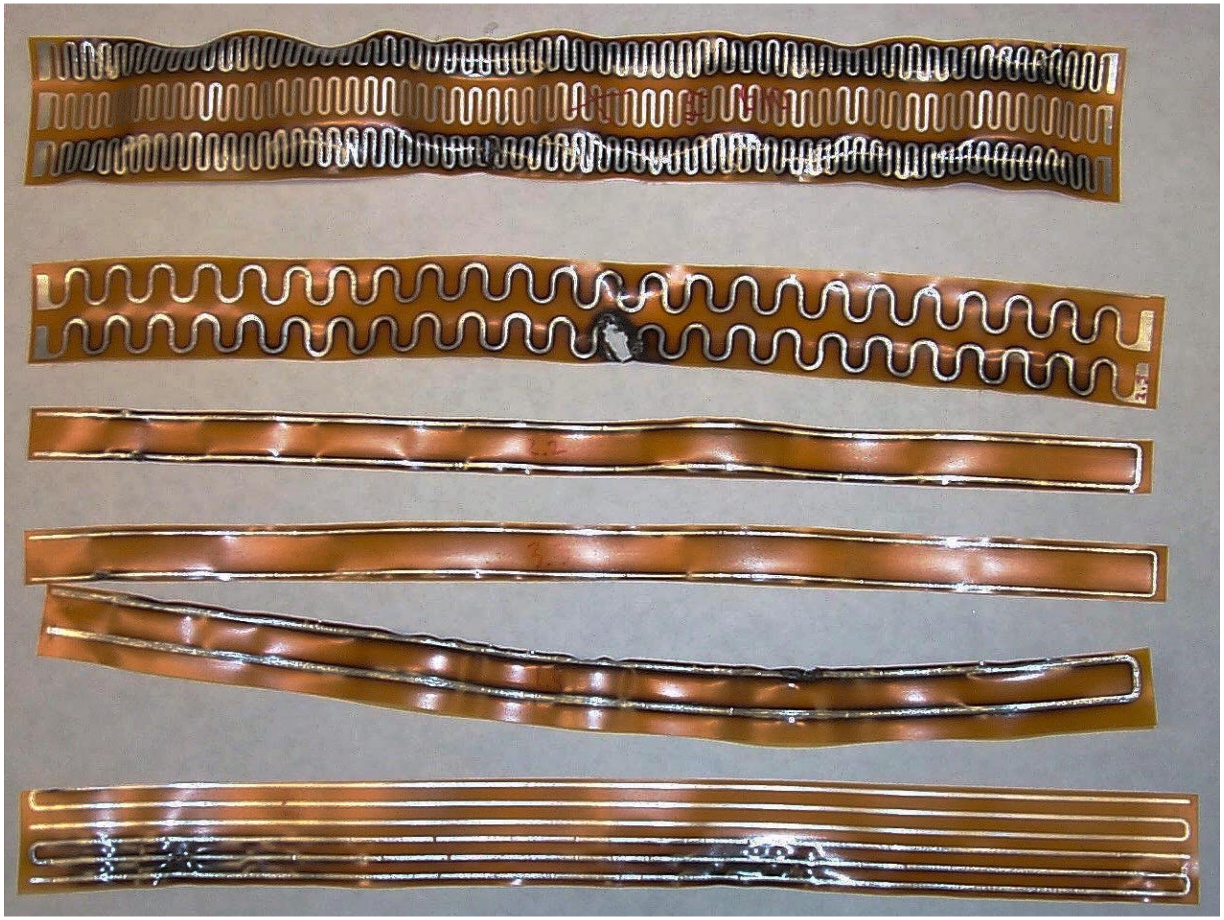
Design goal: 0.03W/cm^2
1-Amp / trace
2 traces / square cm
(traces have 5mm pitch)



Heater laid up and Co-cured with laminate

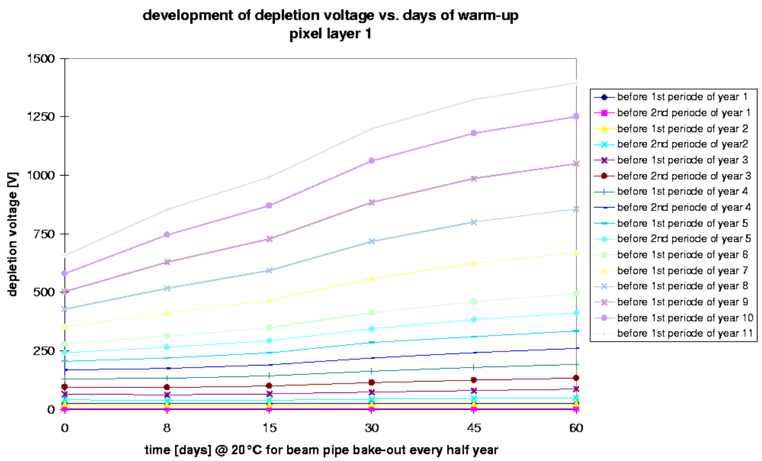
Test Results

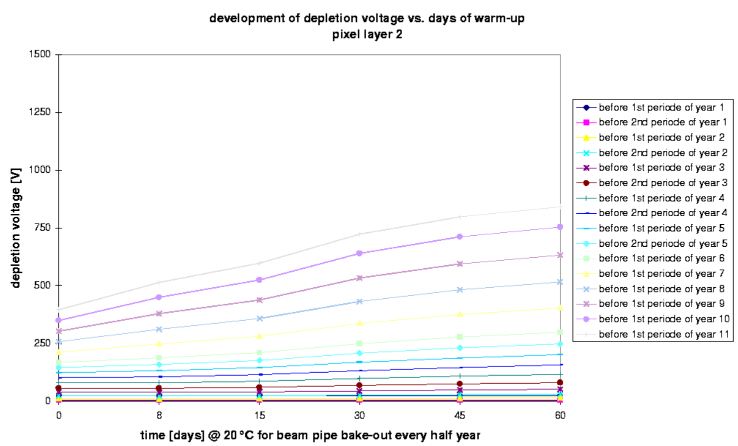




Test heaters fail at over 30X the required power density
IR Camera results show uniform operating temperatures

Is Thermal Barrier Necessary?





B-Layer installation necessitates installation of a Thermal Barrier to prevent condensation on detector elements (in fact all surfaces) within the detector.

Careful attention must be paid to these thermal barriers as they add inactive mass, and reduce available space.

Sensitivity of the Pixel Layers to warm up time as a function of total fluence has been calculated to weigh the need for a thermal barrier

Conclusions

- **Thermal barrier heaters work**
  - Work on heaters is useful also for the active barriers
- **It is unknown if they will be used within pixel volume**
  - Efforts to do away with them are under way
- **Structural impact has yet to be determined**
  - Pressure variations, structural coupling not modeled
  - Service burden not determined